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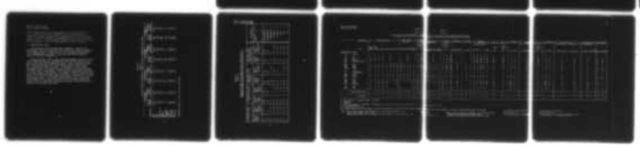

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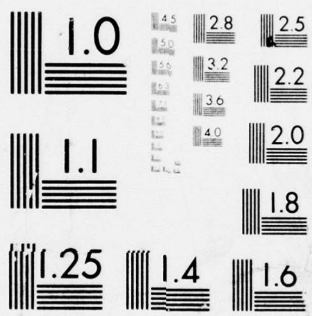

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LASER PROTECTIVE EYEWEAR

August 1977

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SERVING THE ARMY IN ITS PREVENTIVE MEDICINE PROGRAM

SENTINEL of HEALTH

US ARMY
ENVIRONMENTAL HYGIENE AGENCY
ABERDEEN PROVING GROUND, MD 21010

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Laser eye protection often provides the most important control measure in reducing or eliminating ocular hazards from lasers in the laboratory or downrange in a laser target area in field situations. General information on the design characteristics and important parameters to consider in selecting laser eye protection are provided. A list of commercially available laser eye protection with manufacturer specifications is provided.

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DEPARTMENT OF THE ARMY
U S. ARMY ENVIRONMENTAL HYGIENE AGENCY
ABERDEEN PROVING GROUND. MARYLAND 21010

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LASER PROTECTIVE EYEWEAR

1. BACKGROUND. Laser protective eyewear is presently available from several commercial sources and in many varieties. A standard anti-laser goggle is being developed by the Army. Several factors should be considered in determining whether eyewear is necessary and, if so, selecting the proper eyewear for a specific situation. At least two output parameters of the laser must be known, and knowledge of environmental factors such as ambient lighting and the nature of the laser operation is also required. Laser eye protection generally consists of a filter plate or stack of filter plates, or two filter lenses which selectively attenuate at specific laser wavelengths, but transmit as much visible radiation as possible. Eyewear is available in several designs--spectacles, coverall types with opaque side-shields, and coverall types with somewhat transparent side-shields (Figure 1).

2. OPERATIONAL REQUIREMENTS FOR LASER EYE PROTECTION.

a. The experience gained by the US Army Environmental Hygiene Agency from evaluating ocular hazards of a large variety of field and laboratory lasers shows that requirements for eye protection vary considerably The primary usefulness of laser eye protection is in testing of and training with laser devices.

b. Eye protection is normally not recommended for flight crews of aircraft equipped with laser rangefinders and target designators. The added hazards resulting from loss of peripheral vision, reduced visual transmission and degraded color contrast from most types of goggles may outweigh the protection afforded by such goggles from the normally very low probability of exposure from a reflected laser beam. However, if a hazardous specular reflection is likely to be directed toward the aircraft, then aviators can be required to wear high-visibility eye protection (Side-shields,which reduce peripheral vision, may not be necessary due to the very low probability of a hazardous double reflection exposure at typical engagement ranges. See Figure 2.)

c. At present, it is felt that armored vehicle crews do not require personal eye protection within vehicles. However, devices within armored vehicles which could transmit the beam to a crew member (optical sights and, in some instances, view blocks) should be equipped with anti-laser filters. However, if armored crews were to be outside of the vehicle, then such eye protection would be desirable in certain instances where specular reflections could be expected. If an armored vehicle is the target in laser tests or exercises, personal eye protection for the driver, the commander, and other exposed personnel may be required.

Figure 1. Present Commercially Available Laser Eye Protection have a Variety of Designs.

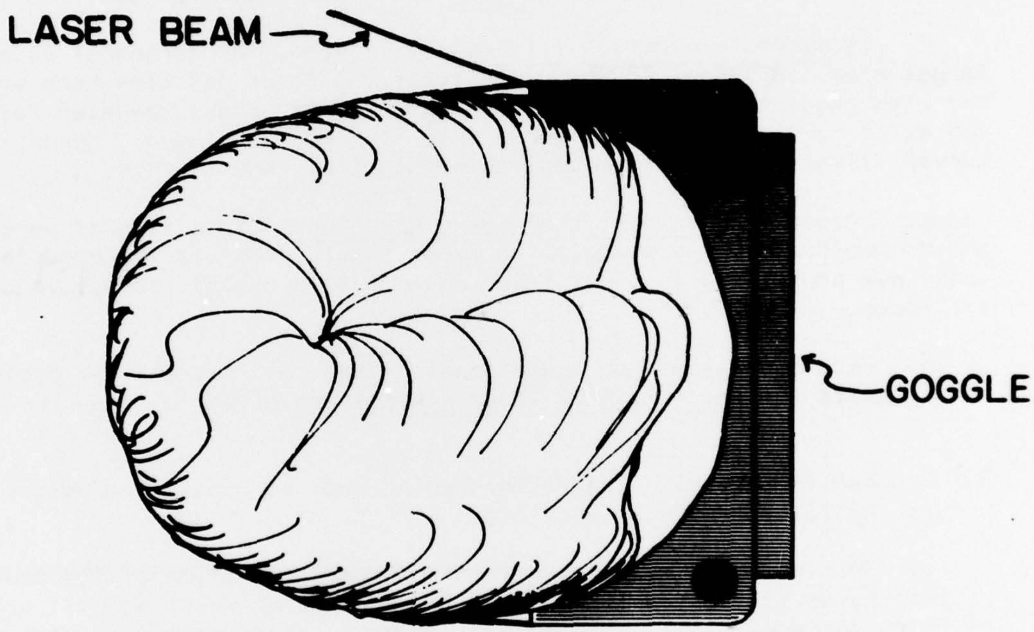

Figure 2. The Potential Hazard of Observing a Specular Reflection or the Primary Beam when Individual is Turned Away from the Laser.

d. In test and training activities, eye protection has been required for personnel downrange within the laser beam target area and for other personnel if the target area cannot be cleared of specular reflective surfaces. However, the more desirable hazard control procedure of removing specular targets from range target areas eliminates the requirement for eye protection for all but the personnel within the target area.

e. For indoor shop or laboratory environments eye protection is required for high-energy or high-power lasers and where viewing the beam is non-essential. However, eye protection has not been recommended for holographic viewing and optical alignment procedures if reasonable precautions are taken.

f. If curved protective filters are required for personnel in a laser target area, personnel in the vicinity of the laser and elsewhere would not also require eye protection. Potentially hazardous specular reflections can exist to significant distances from flat-lens surfaces. Hence, the curved filters are far more desirable than flat lens filters.

g. Proper indoctrination of laser operators not to fire at personnel and to avoid aiming at specular surfaces should preclude the need for laser eye protection from our laser equipment in combat, except in unusual instances.

h. Recommendations for operational hazard controls and eye protection requirements for specific Army laser systems are given in Appendix A Table I

3. EYEWEAR PARAMETERS. The factors which must be considered before purchasing laser safety eyewear are:

a. Wavelength. The wavelength(s) of laser radiation limits the type of eyeshields to those which prevent the particular wavelength(s) from reaching the eye. It is emphasized that many lasers emit more than one wavelength and that each wavelength must be considered. Considering the wavelength corresponding to the greatest output intensity is not always adequate. For instance, a helium-neon laser may emit 100 mW at 632.8 nm and only 10 mW at 1150 nm, but safety goggles which absorb the 632.8 nm wavelength may absorb relatively little or essentially nothing at the 1150 nm wavelength.

b. Optical Density. Optical density is a parameter for specifying the attentuation afforded by a given thickness of any transmitting medium. Since laser beam intensities may be a factor of a thousand or a million

above safe exposure levels, percent transmission notation can be unwieldy. For instance, goggles with a transmission of 0.000001 percent can be described as having an optical density of 8.0. Optical density (O.D.) is a logarithmic notation and is described by the following (mathematical) expression:

$$O.D. = \log_{10} \frac{I_o}{I} \text{ , see Table I}$$

Where I_0 is the intensity of the incident beam and I is the intensity of the transmitted beam. Thus a filter attenuating a beam by a factor of 1,000 or 10^3 has an optical density of 3, and attenuating a beam by 1,000,000 or 10^6 has an optical density of 6. The required optical density is determined by the maximum laser beam intensity to which the individual could be exposed. The optical density of two highly absorbing filters when stacked is essentially the sum of two individual optical densities.

c. Laser Beam Intensity. The maximum laser beam radiant exposure in joules/cm^2 for pulsed lasers or maximum laser beam irradiance in watts/cm^2 for continuous-wave lasers cannot always be readily determined. If the beam is never focused and is larger than the diameter of the eye's pupil, the output energy per unit area or power per unit area should be the guiding value. If the beam is focused or if the beam cannot be observed at the output, the maximum total beam energy or power output must be used.

d. Visible Transmittance of Eyewear. Since the object of laser protective eyewear is to filter out the laser wavelengths while transmitting as much of the visible light as possible, visible (or luminous) transmittance should be noted. A low visible transmittance (usually measured in percent) creates problems of eye fatigue and may require an increase in ambient lighting in laboratory situations. However, adequate optical density at the laser wavelengths should not be sacrificed for improved visible transmittance. For nighttime viewing conditions, the effective visible transmittance will be different since the spectral response of the eye is different. Figure 3 shows the scotopic (night vision) and photopic (cone vision) responses of the eye. Blue-green filter lenses therefore have higher scotopic transmission values than red or orange lenses and vice-versa.

e. Laser Filter Damage Threshold (Maximum Irradiance). At very high beam intensities filter materials which absorb the laser radiation are damaged, thus it becomes necessary to consider a damage threshold for

TABLE I

PERCENT TRANSMISSION vs. OPTICAL DENSITY

Percent	Density	Percent	Density	Percent	Density	Percent	Density	Percent	Density
100.0	0.00	33.11	0.48	10.96	0.96	3.631	1.44	1.20	1.92
92.72	0.01	32.36	0.49	10.72	0.97	3.548	1.45	1.17	1.93
95.50	0.02	31.62	0.50	10.47	0.98	3.467	1.46	1.15	1.94
93.33	0.03	30.90	0.51	10.23	0.99	3.388	1.47	1.12	1.95
91.20	0.04	30.20	0.52	10.00	1.00	3.311	1.48	1.10	1.96
89.13	0.05	29.51	0.53	9.772	1.01	3.236	1.49	1.07	1.97
87.10	0.06	28.84	0.54	9.550	1.02	3.162	1.50	1.05	1.98
85.11	0.07	28.18	0.55	9.333	1.03	3.090	1.51	1.02	1.99
83.18	0.08	27.54	0.56	9.120	1.04	3.020	1.52	1.00	2.00
81.28	0.09	26.92	0.57	8.913	1.05	2.951	1.53	0.89	2.05
79.43	0.10	26.30	0.58	8.710	1.06	2.884	1.54	0.79	2.10
[illegible]	0.11	25.70	0.59	8.511	1.07	2.818	1.55	0.71	2.15
[illegible]	0.12	25.12	0.60	8.318	1.08	2.754	1.56	0.63	2.20
74.13	0.13	24.55	0.61	8.128	1.09	2.692	1.57	0.56	2.25
72.44	0.14	23.99	0.62	7.943	1.10	2.630	1.58	0.50	2.30
70.79	0.15	23.44	0.63	7.762	1.11	2.570	1.59	0.45	2.35
69.18	0.16	22.91	0.64	7.586	1.12	2.512	1.60	0.40	2.40
67.61	0.17	22.39	0.65	7.413	1.13	2.455	1.61	0.36	2.45
66.07	0.18	21.88	0.66	7.244	1.14	2.399	1.62	0.32	2.50
64.57	0.19	21.38	0.67	7.079	1.15	2.344	1.63	0.28	2.55
63.10	0.20	20.89	0.68	6.918	1.16	2.291	1.64	0.25	2.60
61.66	0.21	20.42	0.69	6.761	1.17	2.239	1.65	0.22	2.65
60.26	0.22	19.95	0.70	6.607	1.18	2.188	1.66	0.20	2.70
58.88	0.23	19.50	0.71	6.457	1.19	2.138	1.67	0.18	2.75
57.54	0.24	19.05	0.72	6.310	1.20	2.09	1.68	0.16	2.80
56.23	0.25	18.62	0.73	6.166	1.21	2.04	1.69	0.14	2.85
54.95	0.26	18.20	0.74	6.026	1.22	2.00	1.70	0.13	2.90
53.70	0.27	17.78	0.75	5.888	1.23	1.95	1.71	0.11	2.95
52.48	0.28	17.38	0.76	5.754	1.24	1.91	1.72	0.10	3.00
51.29	0.29	16.98	0.77	5.623	1.25	1.86	1.73	0.09	3.04
50.12	0.30	16.60	0.78	5.495	1.26	1.82	1.74	0.08	3.10
48.98	0.31	16.22	0.79	5.370	1.27	1.78	1.75	0.07	3.15
47.86	0.32	15.85	0.80	5.248	1.28	1.74	1.76	0.06	3.20
46.77	0.33	15.49	0.81	5.129	1.29	1.70	1.77	0.04	3.40
45.71	0.34	15.14	0.82	5.012	1.30	1.66	1.78	0.025	3.60
44.67	0.35	14.79	0.83	4.898	1.31	1.62	1.79	0.016	3.80
43.65	0.36	14.45	0.84	4.786	1.32	1.58	1.80	0.010	4.00
42.66	0.37	14.13	0.85	4.677	1.33	1.55	1.81	0.006	4.25
41.69	0.38	13.80	0.86	4.571	1.34	1.51	1.82	0.003	4.50
40.74	0.39	13.49	0.87	4.467	1.35	1.48	1.83	0.0018	4.75
39.81	0.40	13.18	0.88	4.365	1.36	1.45	1.84	0.0010	5.00
38.90	0.41	12.88	0.89	4.266	1.37	1.42	1.85	0.0006	5.25
38.02	0.42	12.59	0.90	4.169	1.38	1.38	1.86	0.0003	5.50
37.15	0.43	12.30	0.91	4.074	1.39	1.35	1.87	0.00018	5.75
36.31	0.44	12.02	0.92	3.981	1.40	1.32	1.88	0.00010	6.00
35.48	0.45	11.75	0.93	3.890	1.41	1.29	1.89		
34.67	0.46	11.48	0.94	3.802	1.42	1.26	1.90		
33.88	0.47	11.22	0.95	3.715	1.43	1.23	1.91		

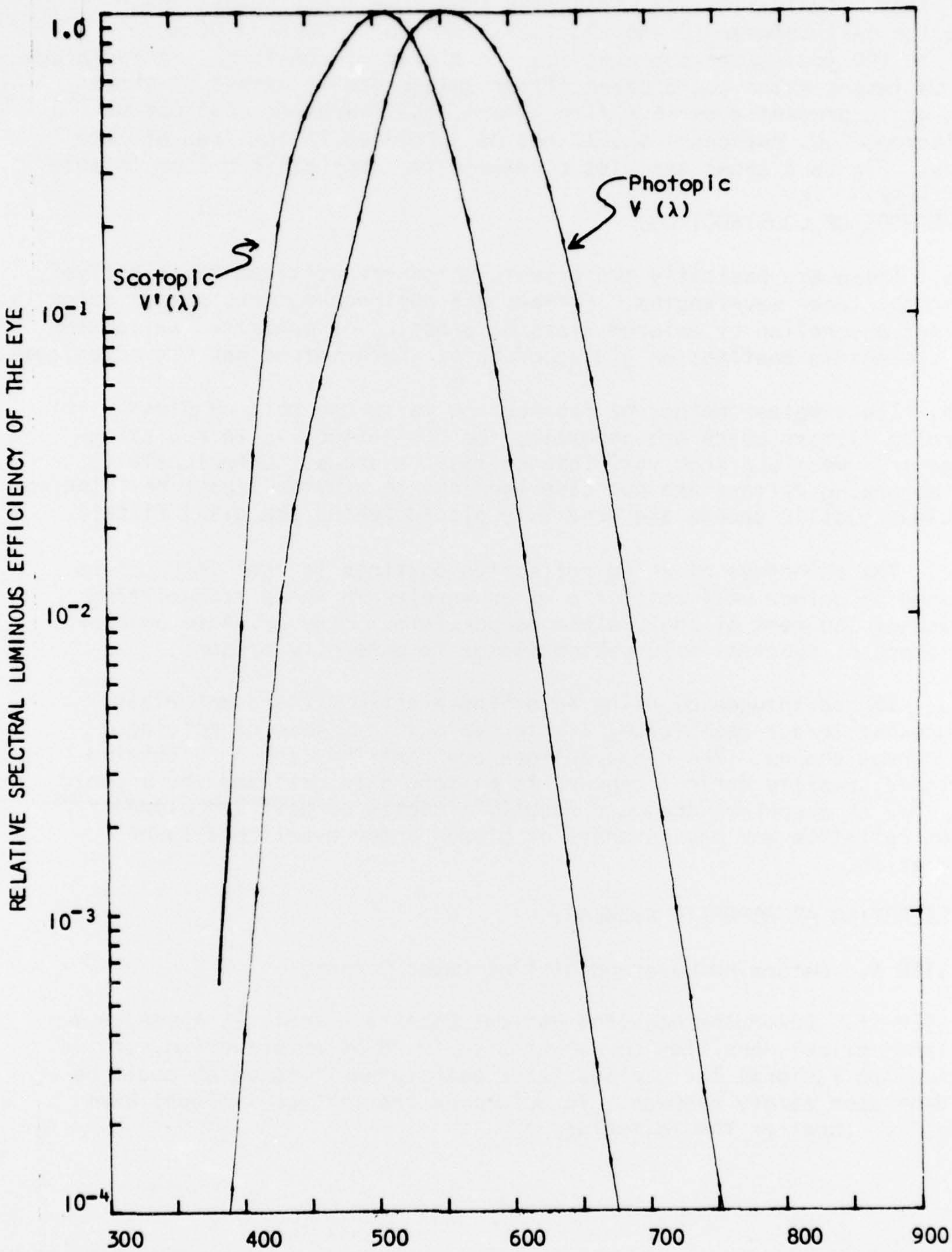

Figure 3 Relative spectral luminous efficiency (normalized) curves for photopic (daylight) and scotopic (night) vision, showing the Purkinje shift of the wavelength of maximum efficiency.

the filter. Typical damage thresholds from q-switched pulsed laser radiation fall between 10 and 100 joules/cm^2 for absorbing glass, and 1 to 100 joules/cm^2 for plastics and dielectric coatings. Irradiances from CW lasers which would cause filter damage are in excess of those which would present a serious fire hazard, and therefore need not be considered, i.e. personnel should not be permitted in the area of such lasers. Figure 4 shows examples of damage to laser filters from intense laser beams.

4. METHODS OF CONSTRUCTION.

a. There are basically two effects which are utilized to selectively filter out laser wavelengths. Filters are designed to make use of selective spectral absorption by colored glass or plastic, or selective reflection from dielectric coatings on glass, or both. Each method has its advantages.

b. The simplest method of fabrication is to use colored glass absorbing filters which are generally the most effective in resisting damage from wear and from very intense laser sources. Unfortunately, most absorbing filters are not case hardened to provide impact resistance, but clear plastic sheets are generally placed behind the glass filter.

c. The advantage of using reflective coatings is that they can be designed to selectively reflect a given wavelength while transmitting as much of the rest of the visible as possible. However, some angular dependence of spectral attenuation factor is generally present.

d. The advantages of using absorbing plastic filters materials are greater impact resistance, lighter weight, and ease of molding into curved shapes. The disadvantages are that they are more readily scratched, quality control appears to be more difficult and the organic dyes used as absorbers are more readily affected by heat and ultra-violet radiation and may saturate or bleach under q-switched laser irradiation.

5. SELECTING APPROPRIATE EYEWEAR.

STEP I. Determine Wavelength(s) of Laser Output.

STEP II. Determine Required Optical Density - Table II, Appendix A required optical densities (or alternatively dB of attentuation, or attenuation factors) for various laser beam intensities which could be incident upon safety eyewear. To determine the maximum incident beam intensity, consider the following:

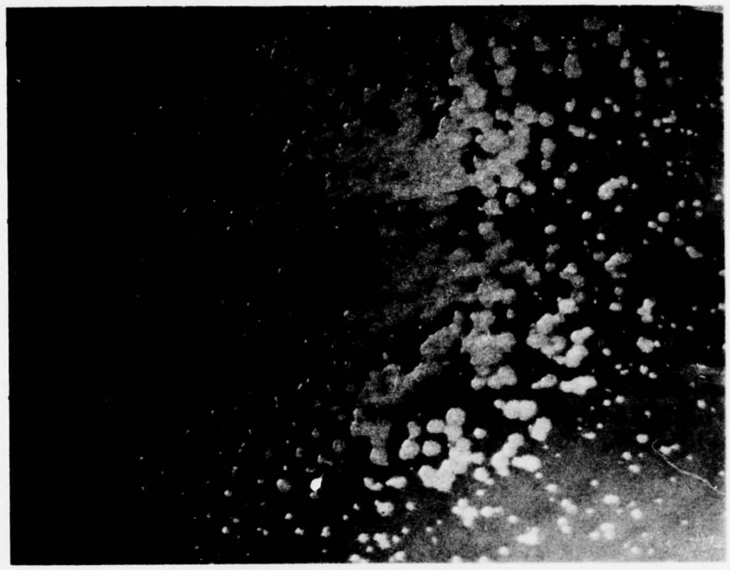

FIGURE 4A. Photomicrograph showing holes formed in dielectric coating of laser goggle filter plate from Q-switched laser beam. Photo indicates damage in this type of laser safety goggle with an incident beam energy density between 1 and 10 Joules/cm^2.

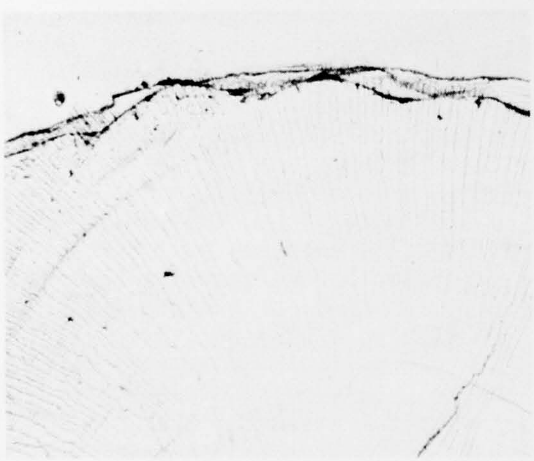

FIGURE 4B. Photomicrograph of absorbing glass filter illustrating concoidal fractures after exposure to 2 Joule Q-switched ruby laser focussed to 2-3 mm spot.

FIGURE 4C. Surface damage of plastic filter caused by radiant exposure of $\sim$ 30 J/cm^2 delivered in μ 2 msec.

a. If the emergent beam is not focused down to a smaller spot, and greater than 7 mm in diameter, the emergent beam radiant exposure/irradiance may be considered the maximum intensity that could reach the unprotected eye, and is thus used in Table II, Appendix A.

b. If the emergent beam is focused after emerging from the laser system or if the emergent beam diameter is less than 7 mm in diameter, one should assume that all of the beam energy/power could enter the eye. In this case divide the laser output energy/power by the maximum area of the pupil (approximately 0.4 cm^2). This radiant exposure or irradiance may be used in Table II, Appendix A.

c. If the observer is in a fixed position and cannot receive the maximum output radiant exposure/irradiance, then a measured value may be used (e.g. downrange from laser beam).

6. COMMERCIAL SOURCES OF LASER EYE PROTECTION. At present no standard Army anti-laser goggle has been produced. However, a variety of commercially available eye protection exists. Table III, Appendix A, presents the optical densities at principal laser wavelengths and for actinic ultraviolet radiation (0.2 - 0.32 μm). Optical densities of selected samples of the above eye protection have been checked by US Army Environmental Hygiene Agency and usually have been found to be within 1 O.D. for specified densities less than 8.

7. TESTING LASER EYE PROTECTION. Eye protection should be checked periodically for integrity. The measurement of eye-protection-filter optical densities in excess of 3 or 4 without destruction of the filter is very difficult. The only activity in the Army presently set up to provide this capability is the US Army Environmental Hygiene Agency as far as is known by this Agency. Because of this problem, requirements originally proposed for many laser hazard control guidelines, that the optical density of protective eyewear be periodically checked, have been deleted. The greatest concern has been with goggles having specified optical densities at or only slightly above the density required for protection. Normally required densities do not exceed 8. Goggles having densities less than 8 are normally designed for use at either the helium-neon or ruby laser wavelengths. Therefore, if a more comprehensive goggle testing program were initiated the goggles which should receive first attention are those having a density less than 8 for the ruby and helium-neon lasers. The US Army Environmental Hygiene Agency periodically checks the optical density of various types of commercial eye protection. In general, the goggles meet or exceed specifications given by the manufacturer (Table III, Appendix A). However, in some rare instances protective filters were shown to have densities less than specified. In one case, the lower density still exceeded 8 and was therefore not of concern. In a second

case, the density was significantly less than a specified density of 6. At present, all evidence indicates that the optical density of commercially available eyewear does not decrease although some plastics become slightly more dense after considerable exposure to solar radiation and due to aging. If optical density checks are desired, eye protection may be forwarded to one of the above agencies following purchase.

8. National Stock Items.

The US Army Natick Development Center developed a standard "anti-laser goggle" which was type classified in 1976, but is not yet available in the supply system. It makes use of a 3-mm thickness of BG-18 glass and is approximately equivalent to Fred Reed Type FR6-PL-BG18-GBS-C listed in Table III of Appendix B.

One each, Goggles, Safety, Laser, FSN 4240-258-2054 is supplied in each Laser Rangefinder Test Set, TS-3375/VVG-1, which will be found at upper echelon laser rangefinder maintenance points. Safety goggles are managed as a supply-status code 3 item by the Defense General Supply Center, ATTN: EGSC-OB2, Richmond, VA 23247. These goggles are not stocked. Procurement action is initiated upon each receipt of a valid requisition. The present cost of each goggle is $67.50 and may be expected to increase in the near future to $75.00 each. The goggles are made of flexible plastic and are equivalent to Glendale Model LGS goggles. They provide an optical density of 6 at 694.3 nm (ruby laser) and an optical density of 30 at 1064 nm (neodymium laser). The luminous transmittance is only slightly more than 20 percent for daytime vision which is not considered optimum for general field use, and since the goggles are plastic, they can be readily scratched if not treated with care.

APPENDIX A

TABLE I

LASER EYE PROTECTION REQUIREMENTS AT SEVERAL DISTANCES (r) FROM VARIOUS LASER SYSTEMS

LASER DEVICE	EYE PROTECTION $r < 0.5km$ INTRABEAM VIEWING	EYE PROTECTION $r < 0.5km$ OPTICALLY AIDED VIEWING (13X)	EYE PROTECTION $0.5 \leq r < 1km$ INTRABEAM VIEWING	EYE PROTECTION $0.5 \leq r < 1km$ OPTICALLY AIDED VIEWING (13X)	EYE PROTECTION $1 \leq r < 5km$ INTRABEAM VIEWING	EYE PROTECTION $1 \leq r < 5km$ OPTICALLY AIDED VIEWING (13X)	EYE PROTECTION $r \geq 5km$ INTRABEAM VIEWING	EYE PROTECTION $r \geq 5km$ OPTICALLY AIDED VIEWING (13X)
AARSS	OD 4.5 @ λ	OD 4.9 @ λ	OD 1.8 @ λ	OD 3.8 @ λ	OD 1.2 @ λ	OD 3.2 @ λ	NONE	OD 2.0 @ λ
ALLD	4.3	5.8	3.7	5.7	3.4	5.4	2.3	4.3
CAP	4.1	5.8	3.2	5.2	2.7	4.7	1.4	3.4
GLAD*	4.4	5.3	2.7	4.7	2.2	4.2	0.8	2.8
GLLD	4.2	5.7	4.1	5.7	3.7	5.6	2.4	4.4
ISTAR MARK II	5.2	5.3	2.7	4.7	3.1	5.1	0.7	2.7
LWL*	5.1	5.3	2.2	4.2	1.5	3.5	NONE	2.2
AN/PAQ1* MULE*	4.2	5.6	2.9	4.9	2.4	4.4	1.1	3.1
ILS NC-10-D	2.8	2.8	NONE	2.3	NONE	1.7	NONE	0.3
OPERATIONAL HORNET	4.1	5.6	3.5	5.5	3.3	5.3	2.2	4.2
OPTIC	4.5	5.7	3.8	5.7	3.5	5.5	2.2	4.2
PAVE KNIFE*	4.4	5.3	2.6	4.6	2.0	4.0	0.8	2.8
PAVE SPIKE*	4.6	5.5	2.9	4.9	2.2	4.2	1.0	3.0
TOW	3.6	5.0	1.7	3.7	1.1	3.1	NONE	1.8
LONG KNIFE*	4.6	6.1	4.1	6.1	3.8	5.8	2.7	4.7

* Tentative estimates for device pending field measurements.

APPENDIX A

TABLE II

SIMPLIFIED METHOD FOR SELECTING LASER EYE PROTECTION FOR INTRABEAM VIEWING FOR WAVELENGTHS BETWEEN 200 AND 1400 nm

Q-Switched Lasers (1 ns to 0.1 ms)		Non-Q-Switched Lasers (0.4 ms to 10 ms)		Continuous Lasers Momentary (0.25 s to 10 s)		Continuous Lasers Long-Term Staring Greater than 3 hrs		Attenuation	
Maximum Output Energy (J)	Maximum Beam Radiant Exposure ($J \cdot cm^{-2}$)	Maximum Laser Output Energy (J)	Maximum Beam Radiant Exposure ($J \cdot cm^{-2}$)	Maximum Power Output (W)	Maximum Beam Irradiance ($W \cdot cm^{-2}$)	Maximum Power Output (W)	Maximum Beam Irradiance ($W \cdot cm^{-2}$)	Attenuation Factor	OD
10	20	100	200	NR	NR	100	200	100,000,000	8
1.0	2	10	20	NR	NR	10	20	10,000,000	7
10^{-1}	2×10^{-1}	1.0	2	10^{3}	2×10^{3}	1.0	2	1,000,000	6
10^{-2}	2×10^{-2}	10^{-1}	2×10^{-1}	100	200	10^{-1}	2×10^{-1}	100,000	5
10^{-3}	2×10^{-3}	10^{-2}	2×10^{-2}	10	20	10^{-2}	2×10^{-2}	10,000	4
10^{-4}	2×10^{-4}	10^{-3}	2×10^{-3}	1.0	2	10^{-3}	2×10^{-3}	1,000	3
10^{-5}	2×10^{-5}	10^{-4}	2×10^{-4}	10^{-1}	2×10^{-1}	10^{-4}	2×10^{-4}	100	2
10^{-6}	2×10^{-6}	10^{-5}	2×10^{-5}	10^{-2}	2×10^{-2}	10^{-5}	2×10^{-5}	10	1

APPENDIX A

TABLE III

OPTICAL DENSITIES AT VARIOUS ULTRAVIOLET, VISIB
FOR STANDARD LASER EYE PROTECTION BASED UP

	MANUFACTURER:	American Optical								Bausch & Lomb					Hadron	
										5W37 Series					112 Serie	
															Previous marketed as TRG	
	MODEL:	580*‡ 586*‡	581* 587*‡	584	585**	588	598	599	698	54‡	55‡	56‡	57‡	58‡	1 †	2
Wavelength (nm)	Source															
<320	(Actinic)	>2	>2	>2	>2		>2					>8			>10	10
325	He-Cd	>2	>2	>2	>2		>2					>8			7	10
332	Neon	>2	>2	>2	>2		>2					>8			5	10
337.1	Nitrogen	>2	>2	>2	>2		>2					>8			2	10
347.1	Ruby (2nd Harmonic)	>2	>2	>2	>2		>2			30		8			2	10
441.6	He-Cd	<1	<1	<1	<1	<1	17	14	12>	17	7	1	1	1	<1	10
457.9	Argon	<1	<1	<1	<1	<1	16	13	11	16	7	<1	<1	1	<1	>10
488	Argon	<1	<1	<1	<1	<1	13	11	10	14	3	<1	<1	1	<1	>10
514.5	Argon	<1	<1	<1	<1	<1	9	8	8	12	<1	<1	<1	1	<1	>10
530	Neodymium (2nd Harmonic)	<1	<1	<1	<1	<1	7	6	6.4	10	<1	<1	1	1	<1	>10
611.8	He-Ne	1	3	<1	1	1	<1	<1	<1	1	<1	10	3	1	3	<1
632.8	He-Ne	2	4	1	3	2.5	<1	<1	<1	<1	<1	13	4	1	4	<1
647.1	Krypton	2	4	1	3	3	<1	<1	<1	<1	<1	14	5	1	7	<1
694.3	Ruby	3	6	5	8	7	<1	<1	<4	<1	<1	15	7	2	>10	<1
840	Ga-As	4	5	13	21	17	<1	<1	<10		<1	5	11	4	>10	<1
905	Ga-As	3	4	14	22	17			11		<1	3	11	5	>10	<1
1060	Neodymium	2	2	11	17	13.8			8.5					8	>10	<1
1084	He-Ne	2	2	10	16	13			8					8	>10	<1
1152	He-Ne	1	1	8	13	11			6					8	>10	<1
	% LUMINOUS TRANSMITTANCE:		10	46	35	33	24	25	5	4.3	57	6.16	~3	3	25	1.5
	COST RANGE††:		C	C	C	C	C	C	C	B	B	B	B	B	C	C

* Type: Spectacle - S (587-586); Goggle - G (581-580)
** 4 mm BG-18
† 5 mm BG-18
†† A is less than $20 ea; B is $20-$40 ea; C is $40-$60 ea; D is $60 to $120 ea; and E is greater than $120 ea.
‡ No longer manufactured
\# OD-4 @ 2800 nm; OD-5 @ 3800 nm

NOTE: Another characteristic of these goggles which should be considered in the selection of laser protective eyewear

SOURCE: American Optical Company, Safety Products Divison, Southbridge, Massachusetts 01550
Bausch & Lomb, Rochester, New York 14602
Glendale Optical Company, Inc., 130 Crossways Park Drive, Woodbury, Long Island, New York 11797

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APPENDIX A

TABLE III

S AT VARIOUS ULTRAVIOLET, VISIBLE AND NEAR INFRARED WAVELENGTHS
D LASER EYE PROTECTION BASED UPON MANUFACTURER'S SPECIFICATIONS

Bausch & Lomb 5W37 Series					Hadron 112 Series Previously marketed as TRG			Spectralab	Omnitech	Glendale LGS, LGU or 7400 Series Clipsite Series					LGA Series	LGB Series	Light West		Fred R… FR6-PL-BG18-G…
4‡	55‡	56‡	57‡	58‡	1†	2	5	Spectrogard	182	NN	HN	A	R	NDGA	NDGA R NN	HDGA DOUB. ND A NN	G1A	G1B	(3mm BG-…
		>8			>10	10	>10	16		>15	>10	20	10	>20	25	25	16	>7	>5
		>8			7	10	>10			15	>10	20	8	25	25	25	5	>7	5
		>8			5	10	>10			15	>10	21	9	25	25	25	3	>7	2
		>8			2	10	>10			16	>10	19	9	24	25	25	2	>7	1.7
0		8			2	10	>10	15		16	>10	18	9	23	25	25	2	>7	1.4
17	7	1	1	1	<1	10	>10	11	<1	<1	1	14	<1	7	<1	14	<1	>7	<1
16	7	<1	<1	1	<1	>10	>10	10	<1	<1	1	14	<1	6	<1	12	<1	>7	<1
14	3	<1	<1	1	<1	>10	>10	8	<1	<1	<1	15	<1	1	<1	11	<1	>7	<1
12	<1	<1	<1	1	<1	>10	>10	7	<1	<1	<1	11	<1	1	<1	7	<1	7	<1
10	<1	<1	1	1	<1	>10	>10	5	<1	<1	<1	5	<1	<1	<1	4	<1	>7	<1
1	<1	10	3	1	3	<1	8	4	2	<1	3	<1	1	<1	<1	<1	2	<1	<1
<1	<1	13	4	1	4	<1	4	5	4	<1	6	<1	3	1	<1	<1	3.4	<1	1.5
<1	<1	14	5	1	7	<1	<1	6	4	<1	5	<1	4	1	1	<1	4	<1	2.2
<1	<1	15	7	2	>10	<1	<1	9	2	<1	2	<1	6	3	6	<1	8.4	<1	5
	<1	5	11	4	>10	<1	<1	18		<1	<1	<1	<1	14	30	4	>20	<1	> 5
	<1	3	11	5	>10	<1	<1	19		<1	<1	<1	<1	16	30	5	>20	<1	> 5
				8	>10	<1	<1	13		<1	<1	<1	<1	16	30	4	>20	<1	> 5
				8	>10	<1	<1	9		<1	<1	<1	<1	10	10	2	19	<1	> 5
				8	>10	<1	<1	9		<1	<1	<1	<1	1	1	<1	17	<1	> 5
.3	57	6.16	~3	3	25	1.5	17.6	7.5	22.5	70	17	45	19	45	20	48			35
	B	B	B	B	C	C	D	D	A	B	B	B	B	B	D	C	B	B	D

is greater than $120 ea.

ion of laser protective eyewear is the maximum irradiance before damage of filter plate.

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, New York 11797

Korad, a Division of Hadron 2520 Colorado Ave. Santa Monica, CA 90404
Light West, Box 257, Van Nuys, California 91408
Spectralab, 12484 Gladstone Avenue, Sylmar, California 92400

Fish-Schurman Corp. 75 Portman Rd.
New Rochelle, NY 10802,
Fred Reed Optical Co., P.O. Box 133
AO Central Research Lab., Southbrid

LGB Series	Light West		Fred Reed Optical Co.		AO Research Lab	Fish-Schurman	
			FR6-PL-BG18-GBS-C	FR6-PL-KG3-GBS-C	Non-standard		
HDGA DOUB. ND A NN	G1A	G1B	(3mm BG-18)	(3mm KG-3)	OLF-61 type glass	1060-9	2800-4#
25	16	>7	>5	<1	1.3	>1	>1
25	5	>7	5	<1	<1	>1	>1
25	3	>7	2	<1	<1	>1	>1
25	2	>7	1.7	<1	<1	>1	>1
25	2	>7	1.4	<1	<1	>1	>1
14	<1	>7	<1	<1	<1	>1	>1
12	<1	>7	<1	<1	<1	>1	>1
11	<1	>7	<1	<1	<1	>1	>1
7	<1	7	<1	<1	<1	>1	>1
4	<1	>7	<1	<1	<1	>1	>1
<1	2	<1	<1	<1	<1	>1	>1
<1	3.4	<1	1.5	<1	<1	>1	>1
<1	4	<1	2.2	<1	<1	>1	>1
<1	8.4	<1	5	<1	<1	>1	>1
4	>20	<1	> 5	<2	2.6	2	1
5	>20	<1	> 5	3	3.8	5	1
4	>20	<1	> 5	4.0	6.1	9	2
2	19	<1	> 5	4.0	6.4	9	2
<1	17	<1	> 5	4.0	7.4	9	2
48			35	76	68	64	78
C	B	B	D	C	E	B	B

Fish-Schurman Corp. 75 Portman Rd.
New Rochelle, NY 10802,
Fred Reed Optical Co., P.O. Box 1336, Albuquerque, NM 87103
AO Central Research Lab., Southbridge, MA 01550